Strategic environmental assessment for invasive species management on inhabited islands

J.C. Russell[1] and C.N. Taylor[2]

[1]School of Biological Sciences and Department of Statistics, University of Auckland, Private Bag 92019, Auckland, New Zealand. <j.russell@auckland.ac.nz>. [2]Taylor Baines & Associates, PO Box 8620, Riccarton, Christchurch, New Zealand.

Abstract Over the past decade the challenges of managing invasive species on inhabited islands have clearly become limiting factors to scaling-up the area of invasive species eradications. Step-change is required to unleash the conservation and restoration potential of biodiversity on inhabited islands around the globe and avoid the pitfalls previous attempts to eradicate invasive species on inhabited islands have fallen into. Strategic environmental assessment (SEA) is a systematic decision support process, aiming to ensure that environmental and other sustainability aspects are considered effectively throughout policy, plan and programme making. Within the framework of SEAs, on target islands eradication planners could implement a number of tools including stakeholder engagement, social impact assessment and economic cost-benefit analysis alongside existing environmental impact assessment. Such a suite of assessments captures the immediate impacts of an eradication operation on a range of values, alongside predicted long-term changes in these tightly coupled socio-ecological systems. In this paper we outline what SEA is, and then contrast invasive species management attempts occurring outside an SEA framework on two similar but also contrasting UNESCO World Heritage islands; Lord Howe Island, Australia and Fernando de Noronha, Brazil. We then demonstrate how an SEA approach to invasive species management would assist planning in New Zealand to eradicate introduced mammalian predators from two large offshore islands in New Zealand; Aotea (Great Barrier Island) and Rakiura (Stewart Island). We conclude with future prospects for applying SEA to invasive species management on inhabited islands.

Keywords: eradication, mammals, New Zealand, social impact assessment, World Heritage

INTRODUCTION

Over the past decade the challenges of managing invasive species on inhabited islands have clearly become limiting factors to scaling-up the area of invasive species eradications on islands (Oppel, et al., 2011; Glen, et al., 2013). This is particularly the case for eradication of small mammalian predators, where step-change in technology (e.g. use of helicopters for aerial delivery of toxin; Howald, et al., 2007) coupled with ongoing incremental advances (e.g. non-target mitigation; Hanson, et al., 2015) mean very large islands are now potential targets of whole-island small mammal eradication, but there has not been a commensurate increase in the knowledge around engaging with resident communities (Russell, et al., 2018). Scaling-up eradications to larger islands is also confounded by additional complexities such as mixed land-tenure and land-use (Holmes, et al., 2015) on larger islands, further complicating the suite of appropriate methods for social engagement and technical implementation.

There are many reasons why there should be an increased emphasis on inhabited islands as targets for biodiversity conservation. Most uninhabited islands are small and, although the number of islands from which invasive species have been eradicated is impressive (e.g. Jones, et al., 2016), as a percentage island land area the total is still low (Russell, et al., 2016a). Some endangered species can only be conserved on large islands (PCE, 2017), while climate change increases the long-term risk profile for small islands as resilient conservation sites (Courchamp, et al., 2014). In the tropics, even small islands can be inhabited (Russell & Holmes, 2015), and small island developing states (SIDS) are particularly poorly represented in invasive mammal eradication statistics (Russell, et al., 2017a). Eradication of invasive mammals on inhabited islands also brings about many other benefits beyond biodiversity conservation, including benefits to agriculture, economies, public health and culture (Russell, et al., 2017a).

To date approaches to community engagement in anticipation of mammal eradication on inhabited islands have been designed and led mainly by biologists with a particular set of values and priorities (e.g. Bell, 2019). They have tended to be ad hoc and have not always drawn upon existing scholarship in community engagement. A new step-change is required to unleash the conservation and restoration potential of biodiversity on inhabited islands around the globe and avoid the pitfalls previous attempts to eradicate invasive species on inhabited islands have fallen in to. In this paper we outline the potential for strategic environmental assessment to enable more consistent assessment of options and engagement with island communities in the context of invasive mammal eradication. We then provide two contrasting illustrative examples of approaches to invasive predator management on two similar UNESCO World Heritage island sites, followed by examples from the two largest inhabited offshore islands of New Zealand. We conclude with recommendations for implementing strategic environmental assessment during planning for invasive species management. We emphasise that much of the scholarship we present here is built upon reflection over the past decade on attempts to eradicate invasive mammals from inhabited islands. These lessons come from the benefit of hindsight and could not be anticipated in advance, so they should not be taken as reflecting poorly on those who initially invested themselves in advocating for invasive mammal eradication. Our purpose is to suggest a way towards better processes and improved outcomes from eradications on inhabited islands.

Strategic Environmental Assessment

Strategic environmental assessment (SEA) is a widely accepted approach to applying impact assessment to policies, plans and programmes, contributing to the planning processes, decision making and the ongoing management of change (Tetlow & Hanusch, 2012). Sustainability assessment is another approach often linked to SEA (Morgan 2012). SEA has been described as "analytical and participatory approaches that aim to integrate environmental considerations into policies,

In: C.R. Veitch, M.N. Clout, A.R. Martin, J.C. Russell and C.J. West (eds.) (2019). Island invasives: scaling up to meet the challenge, pp. 692–697. Occasional Paper SSC no. 62. Gland, Switzerland: IUCN.

plans and programmes and evaluate the inter linkages with economic and social considerations" (OECD, 2006). Applications of SEA include spatial planning, sector planning (e.g. fisheries, energy) and catchment planning (Tetlow & Hanusch, 2012; Taylor & Mackay, 2016).

Importantly, SEA provides an over-arching framework of a collection of tools rather than a single, fixed and prescriptive approach. Such an approach is therefore analogous to best practice in technical implementation of eradications on islands (Keitt, et al., 2015), where just as islands differ ecologically, it is also recognised they differ socially. Thus, in any particular case variations with regards to best, or complete, practice will still take place. Its application is an ongoing adaptive and iterative process which adds value to and builds capacity in existing systems (e.g. island human communities). The sorts of tools that can be considered as contributing to the SEA toolbox for island eradications include:

- Community and stakeholder engagement techniques
- Social profiles/baselines and social impact assessments (SIA)
- Health impact assessments
- Cost benefit analyses
- Ecological baselines and impact assessments (EIA)
- Technical feasibility studies
- Livelihoods analyses
- Social marketing/environmental education
- Environmental and social monitoring
- Institutional analyses and change management (includes ongoing biosecurity planning).

As a toolbox, SEA has been around since about the early 1990s when it developed from a growing realisation that local and project-specific applications of environmental impact assessment are insufficient when environmentally damaging decisions are being made at a more strategic level. SEA has not been widely applied in the context of wildlife management (Taylor, et al., 2004). However, in some countries SEA-like frameworks have been implemented in all but name (e.g. the Resource Management Act in New Zealand provides for the application of SEA and the development of policies and plans for the purposes of natural resource management). Strategic environmental assessment is widely accepted internationally as a critical tool in development planning (e.g. by the World Bank and OECD), where the focus is on impact analysis through to institutional assessment. Strategic environmental assessment is accepted in international development as a way to incorporate environmental considerations across all levels of strategic decision-making including plans, programmes, and policies, setting the context for environmental and social impacts assessments of development projects.

In the context of wildlife management on inhabited islands, we adopt the definition of Russell, et al. (2018) for an inhabited island. Namely that "inhabitation on an island incorporates the basic infrastructure to enable a community to function socially and economically, such as any of schools, churches, community buildings or general shared spaces, alongside enterprises delivering goods and services, and opportunities for residents to pursue a range of livelihood opportunities in the public and private sectors". However, we hasten to add that even when an island is uninhabited, a social framework process may still be required during wildlife management planning where stakeholders and others with vested interests in the island can be identified.

Poor or inconsistent planning is well known in other sectors to delay project completion (Flyvbjerg, 2014). To avoid this problem, we consider wildlife management on islands, and particularly eradication of invasive species, should be treated in the same way as any large-scale, multi-component development project, whereby SEA is a valuable unifying framework that draws together a collection of tools. Many of the tools under SEA are already becoming increasingly applied when planning invasive species management, such as social profiling (Russell, et al., 2018), social impact assessment (Crowley, et al., 2017b), and participatory processes (McEntee & Johnson, 2016). Other tools, such as EIA and economic cost-benefit analyses, can work under the umbrella of SEA for specific eradication projects, once the strategic framework is in place. In particular, eradication practitioners globally should adopt a best practice approach when working with communities on inhabited islands, as they already do for technical best practice when planning the operational elements of eradications on islands (Keitt, et al., 2015).

Most importantly, SEA provides the policy tool by which the role of invasive species eradication as a conservation intervention can cascade throughout all levels of the decision-making process on islands, including deliberative and more participatory approaches (Sims, 2012). This more comprehensive approach applies not just to decisions about wildlife management, but around sustainability of the environment and the livelihoods of human communities on islands. We see this as critical to avoid the pitfalls that previous eradication propositions on inhabited islands haven fallen into – namely where invasive species eradication is considered only as a technical solution to a wildlife management problem on a project by project basis (isolated from other island issues and strategies), and where the support for eradication is seen as merely needing to gain a public consensus through democratic process.

UNESCO WORLD HERITAGE ISLANDS

Many island groups are listed as UNESCO World Heritage sites based on their cultural and natural heritage values. A subset of the islands listed for natural heritage values are also inhabited. In this section we explore the contrasting experiences of enabling introduced small mammal predator management on two similar inhabited UNESCO World Heritage islands where such predator management has been proposed; Fernando de Noronha, Brazil and Lord Howe Island, Australia. These are not the only UNESCO World Heritage islands where predator management takes place. Predator management is also undertaken on Fraser Island, Australia but within the context of a suite of different social and environmental issues related to dingo management (Allen, et al., 2018), and has also been considered on Gough Island (Varnham, et al., 2011), and undertaken on islands in the Galapagos (Carrion, et al., 2011) and Ogasawara Islands (Hashimoto, 2010).

Fernando de Noronha

Fernando de Noronha and Atol das Rocas Reserves in Brazil was assigned UNESCO World Heritage status in 2001. Fernando de Noronha is an archipelago, comprising the primary island of the same name and 20 secondary islands and islets, lying 345 km north east of Brazil in the tropical Atlantic Ocean. The inhabited centre of the island is classified as an Environmental Protection Area (APA), while the uninhabited forested outer areas of the island are part of the Marine National Park (PARNAMAR). Both areas are environmentally administered at the federal level by ICMBio, but socio-politically administered at the state

level by neighbouring Pernambuco state on the continent. The resident population of Fernando de Noronha is estimated at around 3,000 people (IBGE 2016). Tourism is the major enterprise on Fernando de Noronha (de Oliveira, 2003), and an estimated 500 tourists arrive and depart each day. This has led the state government to impose a daily tourist tax for environmental protection <http://www.ilhadenoronha.com.br/ailha/taxadepreservacao_em_noronha.php>. However, it is only the regulation of visitor numbers and not proceeds of the tax which contribute directly to environmental protection.

Today the major invasive species on Fernando de Noronha are cats (*Felis catus*), black (*Rattus rattus*) and brown rats (*R. norvegicus*), and the introduced tegu (*Salvator merianae*) lizard (Abrahão, et al., 2019). In Brazil, invasive species are not widely acknowledged as a threat to biodiversity (Bellard & Jeschke, 2016), and any management of invasive species on Fernando de Noronha typically reflects a public health and continental mind set. Wildlife is managed only in the context of vectors of disease (Magalhães, et al., 2017) while cats are managed as companion animals with strict laws administered from the governing Pernambuco state which do not permit lethal control of cats unless their own welfare is suffering (Dias, et al., 2017). The tegu is a CITES listed native species from continental South America, which is also likely to be having severe predatory impacts on the island fauna (Abrahão, et al., 2019).

Management of invasive species on Fernando de Noronha lacks an island conservation context which acknowledges the severe impact such species are having on the biodiversity of the island, and does not engage in lethal control (Russell, et al., 2016b). These biodiversity impacts are not able to be considered alongside other social and economic issues on Fernando de Noronha, as independent levels and agencies of government are in charge of each separately. Strategic environmental assessment would allow proposals for the management of invasive species on Fernando de Noronha to be placed within their broader social context, where invasive species can be considered both as public health pests and companion animals. Impact assessments of invasive species on both the environment and society are absent but could be contemporaneously created. The island's environmental aesthetic (e.g. beaches) is known to be the main driver of tourism, and generates considerable wealth each year, but it is unknown what role the island's biota (e.g. unique endemic species) play in tourism. Strategic environmental assessment would allow the costs of invasive species on the wider economy to be properly calculated, alongside the potential added value to tourism from invasive species management if not eradication. It would play a role in assessing institutional preparedness for embarking on invasive species management and incorporating invasive species management in wider environmental issues such as pollution and island development. In doing so this would ensure that invasive species management was not marginalised against other critical development issues on the island such as poverty and unemployment.

Lord Howe Island

Lord Howe Island, in Australia, was inscribed UNESCO World Heritage status in 1982. Lord Howe Island is an archipelago, comprising the primary island of the same name and 27 secondary islands and islets, 600 km east of Australia in the Tasman Sea. The island is administered as part of the state of New South Wales and for legal purposes is regarded as an unincorporated area administered by the Lord Howe Island Board which reports to the New South Wales Minister for Environment and Heritage. The resident population of the island is around 350 people. Tourism is the primary enterprise on Lord Howe Island but the Kentia palm (*Howea forsteriana*) industry also contributes to the local economy (Gillespie & Bennett, 2017).

The major invasive species on Lord Howe Island are black rats and mice (*Mus musculus*) (Wilkinson & Priddell, 2011). Eradication of rodents from Lord Howe Island would accrue both biodiversity (Hutton, et al., 2007) and economic benefits (Gillespie & Bennett, 2017). It would specifically facilitate reintroduction of the critically endangered Lord Howe Island stick insect (*Dryococelus australis*) (Hutton, et al., 2007) from its last remaining wild habitat on nearby tiny, precipitous Ball's Pyramid. Eradication of the rats and mice on Lord Howe Island was first proposed in 2001 followed by a series of technical feasibility studies (Saunders & Brown, 2001, Parkes, et al., 2003). Planning commenced in 2006 (Wilkinson & Priddell, 2011) and a draft eradication plan was published in 2009 (LHI Board, 2009). Whereas a number of other eradications of invasive species have occurred on islands belonging to Australia (Priddell, et al., 2011), the eradication of rodents on Lord Howe Island would be the first to take place on an inhabited island, particularly in the strict sense of our more comprehensive definition of inhabitation (i.e. communities and facilities). However, the original proposal to eradicate rodents from Lord Howe Island was met with prolonged resistance by elements of the island community.

Management of invasive species on Lord Howe Island is undertaken in an island conservation context which acknowledges the severe impact such species are having on the biodiversity and economy of the island and engages in lethal control. Nonetheless, on Lord Howe Island resistance to rodent eradication was prolonged from a lack of application of social tools (Russell, et al., 2018), although at the time Lord Howe Island was one of the first inhabited islands where rodent eradication was being actively pursued. Ultimately, a number of tools from SEA have now been applied independently, including an environmental impact assessment (LHI Board, 2016), economic cost-benefit analysis (Gillespie & Bennett, 2017), and human health risk assessment (O'Kane, 2017) Strategic environmental assessment would have allowed the planning of rodent eradication on Lord Howe Island to take place using the most appropriate tools for engaging with a resident community that had unanticipated levels of hostility towards the overall proposal. Tools from an SEA framework would have helped identify the various underlying threads of the resistance to rodent eradication in a community that was already accepting of lethal rodent control for the same values at those proposing rodent eradication. Whereas it was initially believed providing more evidential information on the need for eradication and the expected biodiversity benefits alone would be sufficient to gain support for rodent eradication (Wilkinson & Priddell, 2011), this is now known to play only a small role in invasive species planning (Crowley, et al., 2017a), and SEA would have provided tools for a greater participatory process in the rodent eradication planning on Lord Howe Island.

Summary

Although Fernando de Noronha and Lord Howe Island are very similar in geography, they share only a few consistencies in governance and structure, e.g. on both islands the government remains the land-owner and residents are all lease-holders. Otherwise, the generally vast differences in cultures and governance (Reis & Hayward, 2013) mean that planning for invasive species management must be considered in very different contexts on each island. On Fernando de Noronha SEA would have fostered the consideration of invasive species impacts within wider environmental and societal issues, whereas

on Lord Howe Island SEA would have provided guidance on the appropriate tools for community engagement to move beyond rodent control to eradication. Thus, the over-arching framework of SEA would have been applied differently on each island to reflect their different contexts and experiences.

NEW ZEALAND ISLANDS

New Zealand has led the world in invasive mammal eradications, with about one third of its islands having been cleared of all invasive mammals (Towns, et al., 2013). These successes have spurred the country to propose the Predator Free New Zealand ambition to eradicate stoats (*Mustela erminea*), rats and brushtail possums (*Trichosurus vulpecula*) from the entirety of the archipelago by 2050 (Russell, et al., 2015). A necessary stepping stone to this goal would entail removing invasive mammals from the large offshore islands of Aotea (Great Barrier Island) and Rakiura (Stewart Island), which would immediately raise the amount of offshore island predator-free land area from 10% to 50%. Discussions and limited planning for invasive mammalian predator eradication from both islands have taken place but using different methods to understand the wider context of, and barriers to, invasive mammal eradication.

Aotea

Aotea comprises a main island of 27,761 ha and numerous surrounding islands and islets, located 17 km north-east from the northern North Island of New Zealand. The island falls within the rohe (tribal boundaries) of Ngati Rehua and has about 800 residents. Seventy percent of the land is owned by the New Zealand Government and is administered by the Department of Conservation. Invasive mammalian predators include cats, black rats, Pacific rats (*R. exulans*) and mice. Mustelids, brushtail possums and hedgehogs (*Erinaceus europaeus*) are notably absent. Large predator control projects at the sub-island level currently occur at Windy Hill Sanctuary (770 ha) and Glenfern Sanctuary (230 ha), and invasive mammals have been removed from numerous surrounding offshore islands (Clout & Russell 2006). A number of bird species are currently at risk of island extirpation including red-crowned parakeets (*Cyanoramphus novaezelandiae*) and tomtits (*Petroica macrocephala*), and the last remaining kokako (*Callaeas wilsoni*) were removed in 1994 to nearby Hauturu. Whole-island eradication of feral cats and rodents was first proposed in 2003, but was met with prolonged resistance by elements of the island community (Ogden & Gilbert, 2011).

A number of tools from SEA have been applied independently on Aotea to better understand the position of the local community towards invasive mammalian predator eradication. In 2015 a participatory process was initiated in the community to understand community perspectives and aspirations towards the overall ecology of the island (McEntee & Johnson, 2015; McEntee & Johnson, 2016). This participatory process identified that the community's perspective on invasive mammal eradication could not be disassociated from their broader economic and social aspirations, and that any investment in invasive mammal eradication had to be part of a broader investment in the community itself. It also identified underlying conflicts in the community such as the tension between the value of isolation versus the desire to increase tourism, and between the desire to control invasive predators versus the value of a toxin-free environment.

A social profiling exercise was also undertaken in 2015 alongside an assessment of the community's attitudes to invasive species management (Aley, 2016; Russell, et al., 2018). This exercise found that there was a higher level of uncertainty with respect to supporting eradication than found on other neighbouring islands, but the social profile of Aotea was not markedly dissimilar to other neighbouring islands in the Hauraki Gulf, although all the islands were markedly different from a corresponding sample in neighbouring Auckland city. This suggested overall that the community's position on invasive mammal eradication was potentially driven by unique recent experiences and exposure to ideas, rather than anything in its social profile, although there did appear to be an overriding island archetype for all the islands in the study, even though one had already had invasive rats eradicated from it (Russell, et al., 2018).

Rakiura

Rakiura comprises a main island of 174,600 ha and numerous surrounding islands and islets, located 27 km south from the southern South Island of New Zealand. The island falls within the rohe of Ngai Tahu and has about 450 residents. Eighty-five percent of the land is owned by the New Zealand Government and is administered by the Department of Conservation. Invasive mammalian predators include cats, black rats, brown rats, Pacific rats, brushtail possums and hedgehogs. Mustelids and mice are notably absent. Large predator control projects at the sub-island level currently occur at Mamaku Point Conservation Reserve (172 ha; previously Dancing Star Conservation Estate), and invasive mammals have been removed from numerous surrounding offshore islands (Clout & Russell, 2006). Although a number of endangered bird species rare on the main islands of New Zealand are abundant on Stewart Island, the last remaining kakapo (*Strigops habroptilus*) were removed in 1992 to nearby offshore Whenua Hou. Whole-island eradication of feral cats and rodents was first proposed in 2008 (Beaven, 2008), but was also met with local resistance.

Rakiura is another case where a number of tools from SEA have been applied independently in an ad hoc manner, not preceded by any attempt to better understand the position of the local community towards invasive mammalian predator eradication. In 2013 a technical feasibility study for removing all invasive mammal predators from Rakiura was undertaken (Bell & Bramley, 2013). This technical feasibility study found that the eradication of invasive mammalian predators from Rakiura was not possible with today's technology, but a sub-island level project around Halfmoon Bay would be feasible. Subsequently a sub-island level project (4,800 ha) consisting of a predator-proof fence protecting the northern peninsula at Halfmoon Bay was proposed as an interim step to achieving a predator-free Rakiura, including technical reports on the predator-proof fence design (Bell, 2014a) and predator eradication methodology (Bell, 2014b). The report on the fence design emphasised the necessity of a predator-proof fence in order to achieve invasive mammalian predator eradication on the peninsula, while the report on predator eradication methodology presented a suite of options for the community to be consulted upon.

In 2014, an economic cost-benefit assessment of invasive mammalian predator eradication for both Rakiura and Halfmoon Bay was also undertaken (Morgan & Simmons, 2014). This report found that eradication was unlikely to have a net positive economic gain from tourism alone but became positive with the addition of ecosystem service valuation. The report also emphasised that anticipated economic and social benefits from invasive mammal eradication may not necessarily eventuate unless the community had a plan and processes in place to capitalise upon them. Despite the substantial investment in technical scoping and community lobbying for a predator-

free Rakiura and the Halfmoon Bay project, there remains a level of resistance to both projects on the island along with multiple local proposals and efforts towards enhanced biodiversity (Russell, et al. 2017b).

Summary

The human communities on both Aotea and Rakiura exist in a similar cultural space, and the islands have remarkably similar ecological histories of bird loss, despite being at opposite latitudes of New Zealand. However, both islands illustrate the importance of drawing on the full set of tools available in SEA to build a comprehensive understanding of the perceived and real barriers to implementing an invasive species eradication programme. On Aotea, an SEA approach would have brought the technical and economic aspects of predator eradication into the community discussion earlier, alongside the social elements. When done properly this could have reduced uncertainty in the technical aspects of the proposed eradication, and addressed broader livelihood elements, particularly with respect to the economy, which are important issues on the island. In contrast, on Rakiura an SEA approach would have identified much earlier in the planning process the importance of including social assessment alongside technical and economic cost-benefit assessment, and drawn all three threads together simultaneously to identify that the most immediate barriers to predator eradication on Rakiura, or even in Halfmoon Bay, reflect existing political structures and economic development issues on the island.

DISCUSSION

In this paper we have outlined the process of SEA and how it might specifically be applied to wildlife management, with an emphasis on invasive species management and eradication on inhabited islands. We have reflected on lessons learnt from case studies on four inhabited islands around the world where invasive species are the primary threat to biodiversity, while also impacting on other elements of island livelihoods. Strategic environmental assessment captures a broad suite of tools, including EIA and SIA. Not all of the tools which are a part of SEA may need to be implemented on every island, and SEA allows the application of more context-specific tools such as SIA, and subsequent community engagement and collaborative planning. Importantly, SEA is not a single, linear or one-off process. As stated at the outset, it is an ongoing adaptive and iterative process which adds value to and builds capacity in existing systems. For eradications on inhabited islands the target system is the island community itself, including both human and non-human organisms. This should come as no surprise as it is now readily accepted that environments with humans in them must be managed as joint socio-ecological systems (González, et al., 2008).

We encourage eradication project managers to identify at the outset which SEA tools should be applied in any given project (e.g. Crandall et al. 2018), and to implement those tools in a consistent manner across projects. Governments should also develop a standardised planning and reporting process for invasive species eradication programmes. However, it is important to note that SEA is not a panacea to the challenges faced by practitioners wishing to implement invasive species eradication programmes on islands. Strategic environmental assessment can still be prone to biases either towards values or technical evidence in decision-making processes (Kørnøv & Thissen, 2000). In some cases, whole-island eradication may simply not be an optimal nor achievable goal, due to technical, ecological social, economic or political barriers (Russell, et al., 2015). This does not mean eradication should not remain an aspirational goal (e.g. Predator Free New Zealand), but that in the meantime focus is directed to conservation interventions which maximise return-on-investment in the broadest sense, e.g. invasive species management at the sub-island level.

The application of SEA in a conservation context has the added benefit of bringing wildlife management and invasive species eradication more strongly into the ambit of a broader application of SEA to island development. This would enable the wider benefits of invasive species eradication to be realised, such as on public health (de Wit, et al., 2017) and in primary industry (Nimmo-Bell, 2009). It would also allow the benefits to be incorporated into the international Sustainable Development Goals, such as reduced inequalities through the more equitable distribution of resources for invasive species eradication across developed and developing island nations. For instance, in small island developing states (Russell, et al., 2017a), which are predominantly tropical and home to unique biodiversity not found elsewhere and at risk from invasive species such as mammalian predators (Russell & Holmes, 2015). Undertaking an SEA approach to invasive species eradication on islands will ultimately ensure the longevity of eradications on islands, and alongside enabling eradications on islands in the first instance, will have immediate benefits in the implementation and maintenance of biosecurity on islands (e.g. Russell, et al., 2017a).

ACKNOWLEDGEMENTS

Funding for components of this work were provided by the Ministry of Education, Brazil CAPES grant PVE Project Number 88881.065000/2014-1 and the Department of Conservation, New Zealand contract 36467 to Uniservices. Thanks to Carlos Abrahão, Andrew Walsh, Judy Gilbert and reviewers for their constructive suggestions.

REFERENCES

Abrahão, C., Russell, J.C., Silva, J.C.R., Ferreira, F. and Dias, R. (2019). 'Population assessment of a novel island invasive: tegu (*Salvator merianae*) of Fernando de Noronha'. In: C.R. Veitch, M.N. Clout, A.R. Martin, J.C. Russell and C.J. West (eds.) *Island invasives: scaling up to meet the challenge,* pp. 317–325. Occasional Paper SSC no. 62. Gland, Switzerland: IUCN.

Aley, J. (2016). 'Environmental and Pest Management Attitudes of Hauraki Gulf Island Communities'. MSc thesis. Auckland, New Zealand: University of Auckland.

Allen, B.L., Cox, T.E., Fleming, P.J., Meek, P.D. and Russell, J.C. (2018). 'Wildlife conservation management on inhabited islands'. *Australasian Journal of Environmental Management* 25(1): 1–4.

Beaven, B. (2008). *Scoping the Potential to Eradicate Rats, Cats and Possums from Stewart Island/Rakiura*. Oban: Stewart Island/Rakiura Community & Environment Trust.

Bell, E.A. (2019). 'It's Not All Up in the Air: The development and use of ground-based rat eradication techniques in the UK'. In: C.R. Veitch, M.N. Clout, A.R. Martin, J.C. Russell and C.J. West (eds.) *Island invasives: scaling up to meet the challenge,* pp. 79–87. Occasional Paper SSC no. 62. Gland, Switzerland: IUCN.

Bell, P. and Bramley, A. (2013). *Eliminating Predators from Stewart Island: Scoping Report to Investigate Issues of Technical Feasibility*. Wellington, New Zealand: Department of Conservation.

Bell, P. (2014a). 'Predator Free Halfmoon Bay Project: *Technical Aspects of the Project – Preliminary Outline*'. Wellington, New Zealand: Department of Conservation.

Bell, P. (2014b). *Predator Free Halfmoon Bay Project: The Predator Fence – Preliminary Outline'*. Wellington, New Zealand: Department of Conservation.

Bellard, C. and Jeschke, J.M. (2016). 'A spatial mismatch between invader impacts and research publications'. *Conservation Biology* 30(1): 230–232.

Carrion, V., Donlan, C.J., Campbell, K.J., Lavoie, C. and Cruz, F. (2011). 'Archipelago-wide island restoration in the Galápagos Islands: reducing costs of invasive mammal eradication programs and reinvasion risk'. *PLOS One* 6(5): e18835.

Clout, M.N. and Russell, J.C. (2006). 'The Eradication of Mammals from New Zealand Islands'. In: F. Koike, M.N. Clout, M. Kawamichi, M. de Poorter and K. Iwatsuki (eds.) *Assessment and Control of Biological Invasion Risks,* , pp. 127–141. Gland, Switzerland: IUCN.

Courchamp, F., Hoffmann, B.D., Russell, J.C., Leclerc, C. and Bellard, C. (2014). 'Climate change, sea-level rise, and conservation: keeping island biodiversity afloat'. *Trends in Ecology & Evolution* 29(3): 127–130.

Crandall, S.G., Ohayon, J.L., de Wit, L.A., Hammond, J.E., Melanson, K.L., Moritsch, M.M., Davenport, R., Ruiz, D., Keitt, B., Holmes, N.D., Packard, H.G., Bury, J., Gilbert, G.S. and Parker, I.M. (2018). 'Best practices: social research methods to inform biological conservation'. *Australasian Journal of Environmental Management* 25(1): 6–23.

Crowley, S.L., Hinchliffe, S. and McDonald, R.A. (2017a). 'Conflict in invasive species management'. *Frontiers in Ecology and the Environment* 15(3): 133–141.

Crowley, S.L., Hinchliffe, S. and McDonald, R.A. (2017b). 'Invasive species management will benefit from social impact assessment'. *Journal of Applied Ecology* 54(2): 351–357.

de Oliveira, J.A.P. (2003). 'Governmental responses to tourism development: three Brazilian case studies'. *Tourism Management* 24(1): 97–110.

de Wit, L.A., Croll, D.A., Tershy, B., Newton, K.M., Spatz, D.R., Holmes, N.D. and Kilpatrick, A.M. (2017). 'Estimating burdens of neglected tropical zoonotic diseases on islands with introduced mammals'. *The American Journal of Tropical Medicine and Hygiene* 96(3): 749–757.

Dias, R.A., Abrahão, C.R., Micheletti, T., Mangini, P.R., de Oliveira Gasparotto, V.P., de Jesus Pena, H.F., Ferreira, F., Russell, J.C. and Silva, J.C.R. (2017). 'Prospects for domestic and feral cat management on an inhabited tropical island'. *Biological Invasions* 19(8): 2339–2353.

Flyvbjerg, B. (2014). 'What you should know about megaprojects and why: an overview'. *Project Management Journal* 45(2): 6–19.

Gillespie, R. and Bennett, J. (2017). 'Costs and benefits of rodent eradication on Lord Howe Island, Australia'. *Ecological Economics* 140: 215–224.

Glen, A.S., Atkinson, R., Campbell, K.J., Hagen, E., Holmes, N.D., Keitt, B.S., Parkes, J.P., Saunders, A., Sawyer, J. and Torres, H. (2013). 'Eradicating multiple invasive species on inhabited islands: the next big step in island restoration?' *Biological Invasions* 15(12) :2589–2603.

González, J., Montes, C., Rodríguez, J. and Tapia, W. (2008). 'Rethinking the Galapagos Islands as a complex social-ecological system: Implications for conservation and management'. *Ecology and Society* 13(2): 13.

Hanson, C.C., Jolley, W.J., Smith, G., Garcelon, D.K., Keitt, B.S., Little, A.E. and Campbell, K.J. (2015). 'Feral cat eradication in the presence of endemic San Nicolas Island foxes'. *Biological Invasions* 17(4): 977–986.

Hashimoto, T. (2010). 'Eradication and ecosystem impacts of rats in the Ogasawara Islands'. In: K. Kawakami and I. Okochi (eds.) *Restoring the Oceanic Island Ecosystem*, pp.153–159. Tokyo, Japan: Springer.

Holmes, N.D., Griffiths, R., Pott, M., Alifano, A., Will, D., Wegmann, A.S. and Russell, J.C. (2015). 'Factors associated with rodent eradication failure'. *Biological Conservation* 185: 8–16.

Howald, G., Donlan, C., Galván, J.P., Russell, J.C., Parkes, J., Samaniego, A., Wang, Y., Veitch, D., Genovesi, P., Pascal, M., Saunders, A. and Tershy, B. (2007). 'Invasive rodent eradication on islands'. *Conservation Biology* 21(5): 1258–1268.

Hutton, I., Parkes, J.P. and Sinclair, A.R.E. (2007). 'Reassembling island ecosystems: the case of Lord Howe Island'. *Animal Conservation* 10(1): 22–29.

IBGE. 2016. Censo Demográfico Fernando de Noronha (Pernambuco). <http://cod.ibge.gov.br/V6F>.

Jones, H.P., Holmes, N.D., Butchart, S.H., Tershy, B.R., Kappes, P.J., Corkery, I., Aguirre-Muñoz, A., Armstrong, D.P., Bonnaud, E., Burbidge, A.A., Campbell, K., Courchamp, F., Cowan, P.E., Cuthbert, R.J., Ebbert, S., Genovesi, P., Howald, G.R., Keitt, B.S., Kress, S.W., Miskelly, C.M., Oppel, S., Poncet, S., Rauzon, M.J., Rocamora, G., Russell, J.C., Samaniego-Herrera, A., Seddon, P.J., Spatz, D.R., Towns, D.R. and Croll, D.A. (2016). 'Invasive mammal eradication on islands results in substantial conservation gains'. *Proceedings of the National Academy of Sciences, USA* 113(15): 4033–4038.

Keitt, B., Griffiths, R., Boudjelas, S., Broome, K., Cranwell, S., Millett, J., Pitt, W. and Samaniego-Herrera, A. (2015). 'Best practice guidelines for rat eradication on tropical islands'. *Biological Conservation* 185: 17–26.

Kørnøv, L. and Thissen, W.A. (2000). 'Rationality in decision-and policy-making: Implications for strategic environmental assessment'. *Impact Assessment and Project Appraisal* 18(3): 191–200.

Lord Howe Island Board (2009). *Draft Lord Howe Island Rodent Eradication Plan*. Lord Howe Island: Lord Howe Island Board.

Lord Howe Island Board (2016). *Lord Howe Island Rodent Eradication Project – Public Environment Report*. Lord Howe Island: Lord Howe Island Board.

Magalhães, F.J., Ribeiro-Andrade, M., Souza, F.M., Lima Filho, C.D., Biondo, A.W., Vidotto, O., Navarro, I.T. and Mota, R. A. (2017). 'Seroprevalence and spatial distribution of *Toxoplasma gondii* infection in cats, dogs, pigs and equines of the Fernando de Noronha Island, Brazil'. *Parasitology International* 66(2): 43-46.

McEntee, M. and Johnson, S. (2015). *Enabling an Ecological Vision for Aotea Great Barrier Island: Understanding Community Perspectives and Aspirations*. Auckland, New Zealand: Aranovus Ltd.

McEntee, M. and Johnson, S. (2016). *Aotea Great Barrier Island Ecology Vision: Weaving the Tapestry*. Auckland, New Zealand: Aranovus Ltd.

Morgan, G. and Simmons, G. (2014). *Predator-Free Rakiura: An Economic Appraisal*. Wellington, New Zealand: The Morgan Foundation.

Morgan, R.K. (2012). 'Environmental impact assessment: The state of the art'. *Impact Assessment and Project Appraisal* 30(1): 5–14.

Nimmo-Bell. (2009). *Economic Costs of Pests to New Zealand*. Technical Paper No: 2009/31. Wellington, New Zealand: MAF Biosecurity.

O'Kane, M. (2017). *Report on the Human Health Risk Assessment for the Lord Howe Island's Proposed Rodent Eradication Program*. NSW Chief Scientist & Engineer.

OECD (2006). *Applying Strategic Environmental Assessment: Good Practice Guidance for Development Co-operation*. Organisation for Economic Co-operation and Development. DAC Guidelines and Reference Series, OECD Publishing.

Ogden, J. and Gilbert, J. (2011). 'Running the gauntlet: advocating rat and feral cat eradication on an inhabited island – Great Barrier Island, New Zealand'. In: C.R. Veitch, M.N. Clout and D.R. Towns (eds.) *Island invasives: eradication and management,* pp. 467–471. Occassional Paper SSC no. 42. Gland, Switzerland: IUCN and Auckland, New Zealand: CBB.

Oppel, S., Beaven, B.M., Bolton, M., Vickery, J. and Bodey, T.W. (2011). 'Eradication of invasive mammals on islands inhabited by humans and domestic animals'. *Conservation Biology* 25(2): 232–240.

Parkes, J., Ruscoe, W., Fisher, P. and Thomas, B. (2003). *Benefits, Constraints, Risks and Costs of Rodent Control Options on Lord Howe Island*. Unpublished report to the Lord Howe Island Board. Lincoln, New Zealand: Landcare Research.

PCE. (2017). *Taonga of an Island Nation: Saving New Zealand's Birds*. Wellington, New Zealand: Parliamentary Commissioner for the Environment.

Priddel, D., Carlile, N., Wilkinson, I. and Wheeler, R. (2011). 'Eradication of exotic mammals from offshore islands in New South Wales, Australia'. In: C.R. Veitch, M.N. Clout and D.R. Towns (eds.) *Island invasives: eradication and management*, pp. 337–344. Occassional Paper SSC no. 42. Gland, Switzerland: IUCN and Auckland, New Zealand: CBB.

Reis, A. and Hayward, P. (2013). 'Pronounced particularity: A comparison of governance structures on Lord Howe Island and Fernando de Noronha'. *Island Studies Journal* 8(2): 285–298.

Russell, J.C. and Holmes, N.D. (2015). 'Tropical island conservation: rat eradication for species recovery'. *Biological Conservation* 185: 1–7.

Russell, J.C., Innes, J.G., Brown, P.H. and Byrom, A.E. (2015). 'Predator-free New Zealand: Conservation country'. *BioScience* 65(5): 520–525.

Russell, J.C., Cole, N.C., Zuël, N. and Rocamora, G. (2016a). 'Introduced mammals on Western Indian Ocean islands'. *Global Ecology and Conservation* 6: 132–144.

Russell, J.C., Jones, H.P., Armstrong, D.P., Courchamp, F., Kappes, P.J., Seddon, P.J., Oppel, S., Rauzon, M.J., Cowan, P.E., Rocamora, G., Genovesi, P., Bonnaud, E., Keitt, B.S., Holmes, N.D., Tershy, B.R. (2016b). 'Importance of lethal control of invasive predators for island conservation'. *Conservation Biology* 30(3): 670–672.

Russell, J.C., Meyer, J.Y., Holmes, N.D. and Pagad, S. (2017a). 'Invasive alien species on islands: impacts, distribution, interactions and management'. *Environmental Conservation* 44(4): 359–370.

Russell, J.C., Taylor, C.N. and Aley J.P. (2018). 'Social assessment of inhabited islands for wildlife management and eradication'. *Australasian Journal of Environmental Management* 25(1): 24–42.

Russell, K.J., Taylor, C.N., Balanovic, J.X., Aley, J.P., Harbow, M.A. and Russell, J.C. (2017b). *Predator Free Rakiura Social Impact Assessment*. A report for the Department of Conservation. Auckland, New Zealand: Uniservices Ltd.

Saunders, A. and Brown, D. (2001). *An Assessment of the Feasibility of Eradicating Rodents from the Lord Howe Island Group*. Unpublished report to the Lord Howe Island Board.

Sims, L. (2012). 'Taking a learning approach to community-based strategic environmental assessment: results from a Costa Rican case study'. *Impact Assessment and Project Appraisal* 30(4): 242–252.

Taylor, C.N., Bryan, C.H., Goodrich, C.G. (2004) *Social Assessment: Theory, Process and Techniques*. Middleton, Wisconsin: Social Ecology Press.

Taylor, C.N. and Mackay, M. (2016). 'Practice issues for integrating strategic social assessment into the setting of environmental limits: insights from Canterbury, New Zealand'. *Impact Assessment and Project Appraisal* 34(2): 110–116.

Tetlow, M.F. and Hanusch M. (2012). 'Strategic environmental assessment: the state of the art'. *Impact Assessment and Project Appraisal* 30(1): 15–24.

Towns, D.R., West, C.J. and Broome, K.G. (2013). 'Purposes, outcomes and challenges of eradicating invasive mammals from New Zealand islands: an historical perspective'. *Wildlife Research* 40(2): 94–107.

Varnham, K., Glass, T. and Stringer, C. (2011). 'Involving the community in rodent eradication on Tristan da Cunha'. In: C.R. Veitch, M.N. Clout and D.R. Towns (eds.) *Island invasives: eradication and management*, pp. 504–507. Occassional Paper SSC no. 42. Gland, Switzerland: IUCN and Auckland, New Zealand: CBB.

Wilkinson, I.S. and Priddel, D. (2011). 'Rodent eradication on Lord Howe Island: challenges posed by people, livestock, and threatened endemics'. In: C.R. Veitch, M.N. Clout and D.R. Towns (eds.) *Island invasives: eradication and management*, pp. 508–514. Occassional Paper SSC no. 42. Gland, Switzerland: IUCN and Auckland, New Zealand: CBB.